2. Covariance

Covariance

Claim Term	CMU's Construction	Marvell's Construction
covariance **'839 Patent Claims 11, 16, 19, 23** **'180 Patent Claim 6**	none; see "noise covariance matrices" **CMU Brf. at 27**	the expected (mean) value of the product of (r_i-m_i) and (r_j-m_j), where r_i and r_j are observed signal samples (at time I and time j, respectively) and m_i and m_j are the expected (mean) values of the samples (at time i and time j, respectively) (i.e., $E[(r_i-m_i)(r_j-m_j)]$). **Marvell Brf. at 21-24**

- Dispute
  - Should "covariance" have its ordinary meaning (Marvell) or be read out of the claim (CMU)?

Claim Language

- Covariance is used to calculate the correlation-sensitive branch metrics

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outputting said branch weight.

11. A method for detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols stored on a high density magnetic recording device, comprising the steps of:

(a) performing a Viterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;
(b) outputting a delayed decision on the recorded symbol;
(c) outputting a delayed signal sample;
(d) adaptively updating a plurality of noise covariance matrices in response to said delayed signal samples and said delayed decisions;
(e) recalculating said plurality of correlation-sensitive branch metrics from said noise covariance matrices using subsequent signal samples; and
(f) repeating steps (a)–(e) for every new signal sample.

12. The method of claim 11 wherein said Viterbi-like sequence detection is performed using a PRML algorithm.

13. The method of claim 11 wherein said Viterbi-like sequence detection is performed using an FDTS/DF algorithm.

14. The method of claim 11 wherein said Viterbi-like sequence detection is performed using an RAM-RSE algorithm.

15. The method of claim 11 wherein said Viterbi-like sequence detection is performed using an MDFE algorithm.

16. A method for detecting a sequence that exploits the correlation between adjacent signal samples for adaptively detecting a sequence of symbols through a communications channel having intersymbol interference, comprising the steps of:

(a) performing a Viterbi-like sequence detection on a plurality of signal samples using a plurality of correlation sensitive branch metrics;
(b) outputting a delayed decision on the transmitted symbol;
(c) outputting a delayed signal sample;
(d) adaptively updating a plurality of noise covariance matrices in response to said delayed signal samples and said delayed decisions;
(e) recalculating said plurality of correlation-sensitive branch metrics from said noise covariance matrices using subsequent signal samples; and

19. A detector circuit for detecting a plurality of data from a plurality of signal samples read from a recording medium, comprising:

a Viterbi-like detector circuit, said Viterbi-like detector circuit for producing a plurality of delayed decisions and a plurality of delayed signal samples from a plurality of signal samples;

a noise statistics tracker circuit responsive to said Viterbi-like detector circuit for updating a plurality of noise covariance matrices in response to said delayed decisions and said delayed signal samples; and

a correlation-sensitive metric computation update circuit responsive to said noise statistics tracker circuit for recalculating a plurality of correlation-sensitive branch metrics from said noise covariance matrices, said branch metrics output to said Viterbi-like detector circuit.

See '839 Patent Claims 11, 16, 19, 23; '180 Patent Claim 6

Claim Language

- "Covariance" is used independently without "noise covariance matrices"

10. A method of generating a branch weight for branches of a trellis for a Viterbi-like detector, wherein the detector is used in a system having Gaussian noise, comprising:

selecting a plurality of signal samples, wherein each sample corresponds to a different sampling time instant;

calculating a first value representing a logarithm of a quotient of a determinant of a trellis branch dependent covariance matrix of said signal samples and a determinant of a trellis branch dependent covariance matrix of a subset of said signal samples;

calculating a second value representing a quadratic of said signal samples less a plurality of target values normalized by a trellis branch dependent covariance of said signal samples;

calculating a third value representing a quadratic of a subset of said signal samples less a plurality of channel target values normalized by a trellis branch dependent covariance of said subset of signal samples;

calculating the branch weight from said first, second, and third values; and

'839 Patent at Claim 10

Specification

- Covariance used in mathematical calculations

correspond to these samples. They are used to compute the vector $\underline{N}_i$, with which the empirical rank-one covariance matrix $\underline{N}_i$, $\underline{N}^T_i$ is formed. In the absence of prior information, this rank-one matrix is an estimate for the covariance matrix for the detected symbols. In a recursive adaptive scheme, this rank-one data covariance estimate is used to update the current estimate of the covariance matrix $\hat{C}(\hat{a})$. A simple way to achieve this is provided by the recursive least-squares (RLS) algorithm. The RLS computes the next covariance matrix estimate $\hat{C}'(\hat{a})$ as:

$$\hat{C}'(\hat{a})=\beta(t)\hat{C}(\hat{a})+[1-\beta(t)]\underline{N}_i\underline{N}_i^T \quad (2$$

'839 Patent 9:45-56

Suppose that, prior to making the decision $\{\hat{a}_i, \hat{a}_{i+1}, \hat{a}_{i+2}\}=\{\ominus, +, -\}$, the estimate for the covariance matrix associated with this sequence of three symbols is

$$\hat{C}(\ominus,+,-)=\begin{bmatrix} 0.5 & -0.2 \\ -0.2 & 0.8 \end{bmatrix} \quad (24)$$

Let the forgetting factor be B=0.95. To update the covariance matrix the vector is first formed:

$$\underline{N}=[(r_i-1)(r_{i+1}-0)]^T=[-0.1-0.2]^T \quad (25)$$

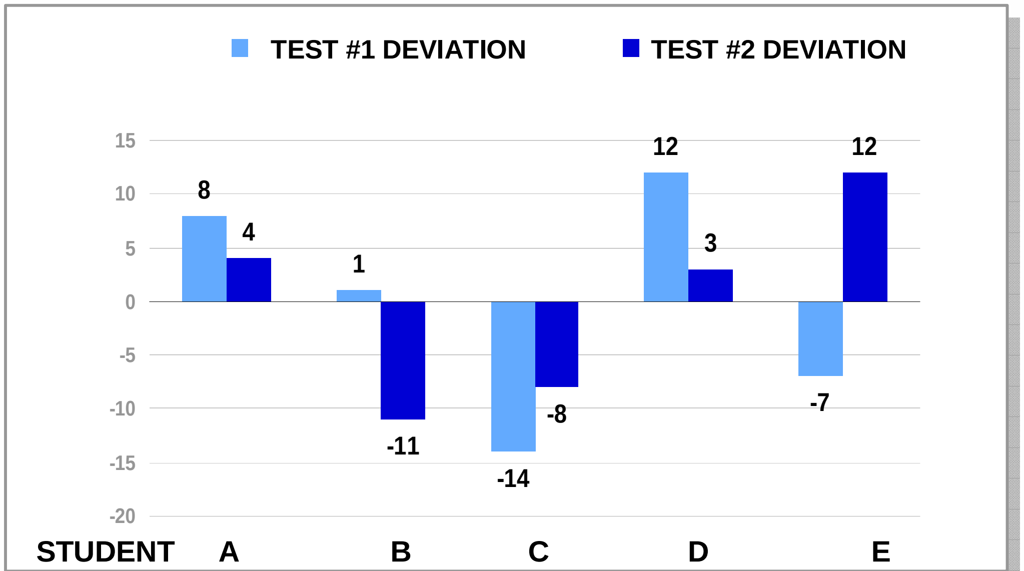
The rank-one sample covariance matrix $\underline{N}\ \underline{N}^T$ is used to find the covariance matrix update:

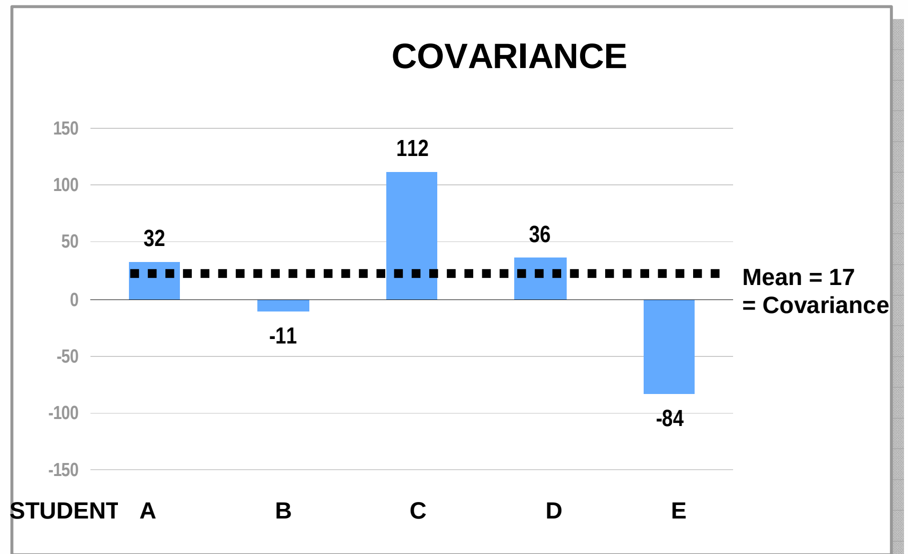
'839 Patent 10:53-67

Background: Statistical Meaning

(Marvell Tutorial Slide 64)

COVARIANCE **the average of the pairwise products of test score deviations.**





	TEST #1 SCORE	TEST #1 MINUS MEAN	DEVIATION SQUARED	TEST #2 SCORE	TEST #2 MINUS MEAN	TEST #1 x TEST #2 PRODUCT	TEST #1 DEVIATION x TEST #2 DEVIATION
STUDENT A	92	8	64	87	4	8004	32
STUDENT B	85	1	1	72	-11	6120	-11
STUDENT C	70	-14	196	75	-8	5250	112
STUDENT D	96	12	144	86	3	8256	36
STUDENT E	77	-7	49	95	12	7315	-84
	SUM 420		SUM 454	SUM 415		SUM 34945	SUM 85
	÷5 84		÷5 91	÷5 83		÷5 6989	÷5 17
	MEAN	DEVIATION	VARIANCE	MEAN	DEVIATION	CORRELATION	COVARIANCE

Extrinsic Evidence: Technical Treatises

- Marvell construction identical to ordinary meaning
  - "the expected value of the product of the deviations of two random variables from their respective means."

The second joint *centralized* moment is called the *covariance*, and is denoted by K_{XY}:

$$K_{XY} \triangleq E\{(X - m_X)(Y - m_Y)\}. \qquad (2.21)$$

Gardner, *Introduction to Random Processes with Applications to Signals and Systems*, at 32 (1986) (Marvell Exh. 24)

The *covariance* of two random variables X and Y, written $\mathrm{Cov}(X, Y)$ is defined by

$$\mathrm{Cov}(X, Y) = E[(X - \mu_x)(Y - \mu_y)]$$

where μ_x and μ_y are the means of X and Y, respectively.

Ross, *Introduction to Probability and Statistics for Engineers and Scientists*, at 119 (2000) (Marvell Exh. 17)

  - *See also* Proakis Decl. at ¶¶ 34-35.
  - Same definition in technical treatises and general dictionaries

co·vari·ance \ˌkō-ˈver-ē-ən(t)s, -ˈvar-; ˈkō-ˌ\ *n* (1931) **1 :** the expected value of the product of the deviations of two random variables from their respective means **2 :** the arithmetic mean of the products of the deviations of corresponding values of two quantitative variables from their respective means

Merriam-Webster's Collegiate Dictionary (10th ed. 1995) (Marvell Exh. 15)